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Research Article

Corona Ions from Powerlines: Production and Effects on Human Health

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Abstract— Overhead Power transmission lines are made of long cylindrical conductor(s), which run parallel to the ground and are mechanically suspended above ground level at regular intervals by towers. There is significant interest in suggestions for creating links between powerlines and some human adverse effects. Such health effects are alleged to be strongest amongst populations directly exposed to high-voltage powerlines. Powerlines are known to aid the production of air ions in a direction perpendicular to the powerlines. These air ions are called corona ions. In this study, our team of researchers meticulously measured the air ion concentrations with an Alphalab Air Ion Counter, a battery-operated instrument that samples atmospheric air. Negative and positive ions are detected separately by selecting a polarity switch. Microsoft Excel 2019 package was used to plot graphs of data collected. Graphs using the same origin were generated, and the curves were compared to finalize the analysis. Corona ion concentration was observed to reduce as we move further away from the centre of the powerline. High-voltage power lines at 11 kV and 132 kV emit significant corona ion discharges, resulting in elevated ion concentrations near the lines that gradually decrease with distance. The findings suggest potential localized air quality impacts influenced by environmental factors like wind and terrain. The observed asymmetry in ion distribution highlights the need to consider site-specific conditions when assessing the environmental and health effects of these discharges. This study suggested that corona ions may enter the body by inhalation and may be deposited in the respiratory system. This may lead to significant and potentially severe health effects on people living in close proximity to powerline areas, highlighting the urgent need for further research and potential mitigation measures. The potential severity of these health effects cannot be overstated, making the need for further research and mitigation measures all the more urgent.

Keywords— Conductor, electric field, transmission, voltage, overhead.

1. Introduction

As consumer demand for electricity grows, electricity generation and distribution companies are seeking methods to increase transmission voltages without significant losses or the need for excessively large conductors. This has resulted in the construction and deployment of additional high-voltage overhead powerlines to enhance electricity transmission and distribution. Corona ions are the air ions produced when air molecules come in contact or come very close to the surface of the conductors of an overhead high-voltage powerline [1]. The alternating electric field generated by a high-voltage (HV) power cable can be sufficiently intense to ionize air molecules, producing corona ions [2].

Ions are generated through a process called corona avalanching, in which electrons are accelerated by the cable's alternating electric field, either towards or away from it. These accelerated electrons collide with air molecules, resulting in the creation of additional ion-electron pairs [3, 4, 5]. The electric field becomes more intense in the presence of protrusions, such as dirt or water droplets on the line, leading to an increased generation of ions [6]. As powerlines are widespread, understanding how corona ions interact with the environment, particularly with airborne pollutants, is crucial for assessing potential ecological impacts. Investigating the effects of corona ions on human health is essential to determine if prolonged exposure poses any risks, especially for populations living near high-voltage powerlines.

2. Related Work

Recently, the impact of factors like thermal radiation, magnetic nanoparticles, electric fields, and radiation on human health and the importance of understanding blood flow and its effects has gained attention [7]. Exposure to electromagnetic fields has raised concerns due to its effects on living organisms' reproductive and physiological systems [8].

High-voltage power lines emit corona ions, which can significantly affect the surrounding environment, particularly concerning atmospheric aerosols and the Earth's natural DC electric field. Studying these effects is crucial in understanding the potential health implications, such as increased lung deposition of pollutants due to altered aerosol behaviour in the vicinity of power lines. Corona Ions and DC Electric Field Modifications [9].

Fews *et al*. [9] conducted a comprehensive investigation into the emission of corona ions from high-voltage power lines and their impact on the DC electric field at ground level. Using a DC field mill meter, the researchers mapped the DC fields near power lines with varying voltages (132 kV, 275 kV, and 400 kV). Their findings demonstrated that the Earth's natural DC field, typically around 100 V/m, was significantly altered in the vicinity of powerlines in a majority of the cases studied. Notably, the direction of the field was often reversed downwind of the power lines, with recorded values reaching as extreme as -340 V/m. In one instance, this effect extended more than 500 meters from a 275 kV power line.

The study further analyzed the charge density required to produce these observed changes in the DC field. It was estimated that approximately 2000 excess negative charges per cubic centimetre were necessary to match the measured DC fields. This elevated space charge leads to unipolar aerosol charging, deviating from the normal bipolar charge distribution typically observed in pollutant aerosols. The implication of this unipolar charging is significant, as it may result in increased lung deposition of aerosols upon inhalation, potentially exacerbating respiratory health risks [9].

In a related study, Matthews *et al*. [10] focused on measuring local electric field variations and space charges near high-voltage power lines. Their research involved using field meters to monitor electric field changes upwind and downwind of power lines and deploying a fixed-site monitoring station to record space charge levels continuously. Additionally, the researchers employed custom-built mobility spectrometers to analyze the high-resolution mobility spectra of atmospheric ions and charged small aerosols.

The results of this study corroborated the findings of Fews *et al*. [9], revealing an increase in the charge state of small aerosols at ground level in the vicinity of power lines. The observed space charge showed high variability, particularly downwind of the power lines. This suggests that the corona ions emitted by the powerlines influenced the aerosol charge distribution in the surrounding atmosphere.

The combined findings from these studies highlight the potential environmental and health impacts of corona ions emitted from high-voltage power lines. Modifying the Earth's DC electric field and the subsequent unipolar charging of aerosols may lead to increased exposure to pollutant aerosols, with potential implications for respiratory health. The increased lung deposition of charged aerosols, as suggested by Fews *et al*. [9], could pose a significant risk, particularly for individuals residing in close proximity to high-voltage power lines.

Overall, these studies underscore the importance of further research into the effects of corona ions on atmospheric aerosols and the potential health risks associated with exposure to altered aerosol charge distributions. Understanding these mechanisms is essential for developing appropriate guidelines and mitigation strategies to minimize the potential adverse effects on public health.

Corona discharge results in a characteristic crackling sound, heat loss, and a visible glow, with power losses ranging from 0.1 mAm to 1.0 mAm, as estimated by Abdel-Salam and Abdel-Aziz [11]. This corresponds to up to 6.3-1014 charges per second per meter of line. However, a significant portion of these charges recombines or is absorbed by the pylons, with only a small fraction escaping downwind. High electric fields caused by voltages in the thousands of volts can lead to the electrical breakdown of air molecules through corona discharges. While powerlines are typically designed to minimize corona discharge in dry conditions, they are more prone to it during wet weather when water droplets on the conductor surface intensify the electric field. Corona ions, created during this process, are attracted to or repelled from the line in a 50 or 60 Hz cycle. Crosswinds can carry some ions away from the line, leading to charge separation between positive and negative ions and the formation of unipolar clouds of space charge [12]. This process, influenced by weather conditions and cable state, causes variations in the density of corona ions discharged. The wind disperses these ions, and they can transfer charge to aerosols, including pollutants, altering their charge state [13, 14, 15].

To date, no specific study has assessed the real-world effects of exposure to charged particles generated by corona ions [16], indicating a potential gap in field and laboratory research needed to underpin essential scientific investigations on this topic. This research aims to explore the potential connections between corona ions from overhead high-voltage powerlines and the generation of ambient charged particles. Understanding the actual concentration levels of these ions and particles around energized powerlines and their potential impact on human health from prolonged exposure is crucial.

3. Experimental Method/Procedure/Design

This study employed a methodology based on the use of a portable AlphaLab Incorporation Air Ion Counter (AIC). In order to ensure accuracy in the measurement of distance, the tape rule was engaged.

Study Area

The study area for this work was the 132kV Powerline located in the Ijoka area in Akure South Metropolis and the

11kV powerline located in the Supare - Akungba Road, Akoko South-West area, both in Ondo State, Nigeria. Both powerlines are over 1km away from residences, industries, and major roads.

Instrumentation

Air ion concentrations were measured using an AlphaLab air ion counter, a battery-operated device designed to sample atmospheric air. The instrument detects negative and positive ions separately by using a polarity switch. The instrument used in this study is discussed below:

a. Air Ion Counter (AIC)

The Air Ion Counter (AIC: The AlphaLab Inc.) used in this study is the standard model measuring up to two million ions/cm^3 with a maximum measuring range of 1,999,000 ions/cm^3. The real-time measuring instrument is equipped with settings to measure positive ions, negative ions, and the net ion concentration in any air environment. To take a measurement, position the meter so that its top is in the air region to be assessed and select the desired polarity. When the polarity switch is activated, the display will initially show a high value, which will then stabilize within ten seconds. At this point, flip the right switch to activate the fan, and the display will indicate the correct concentration of ions per cubic centimetre in the air. During operation, air is drawn through an upper inlet and expelled through a hole at the base of the device. Ions impacting the internal collector plate of the instrument affect its voltage, which is then displayed as the ion concentration (ions/cm^3 of air). In this study, the Air Ion Counter was used to measure net ambient ions.

Figure 1. Air Ion Counter

b. Tape Rule

The tape rule was used to measure the distance between each conductor at ground level and the distance between each measurement point starting from the conductors on the extreme side of the powerline.

Figure 2. Tape Rule

Measurement Technique

Previously, corona ion measurements have been shown to induce atmospheric electricity modifications near HV power lines [15]. This study measured the corona ion count from the respective powerlines by making the conductor at the centre the reference point (zero point). The distance between the left-hand side conductor and the reference point (zero point) was measured (-a). Also, the distance between the right-hand side conductor and the reference point (zero point) was measured (+a). The subsequent distances were taken starting from -a and +a, respectively, at an interval of 5 meters. All distances were measured using the Tape Rule provided.

As explained above, the digital air ion counter was used to measure the air ions by standing upright at the set distances. The random readings were noted to calculate the average. When the power line was energized and emitting corona ions, the readings obtained could only indicate the ion concentration produced by the line rather than a precise measurement. Switching on the instrument typically took about one minute to achieve a stable reading.

In this study, the background DC electric field was measured on level ground, away from any objects that could influence the readings, with no external ionizers present during the measurement.

The instruments were placed directly under the power lines at each measurement site. However, ground-level ion concentration measurements often do not accurately reflect the total ion concentrations emitted by the lines above. Electric field measurements have demonstrated that the wind can carry away these ions and may not reach the ground at significant distances from the lines [17].

Line Characteristics

The two sites investigated contained 1 to 3 parallel sets of Alternate Current (AC) transmission voltage lines 9L1, L2, and L3). The lines were energized during all measurement periods.

Tools for Interpretation of Results

The Microsoft Excel package (2019 version) was used to plot graphs of the collected data. Graphs using the same origin were generated, and the curves were compared to finalize the analysis.

4. Results and Discussion

The measurement of positive and negative ions along both +x and -x axes on 11kV and 132kV were shown in Figure 3 to Figure 6.

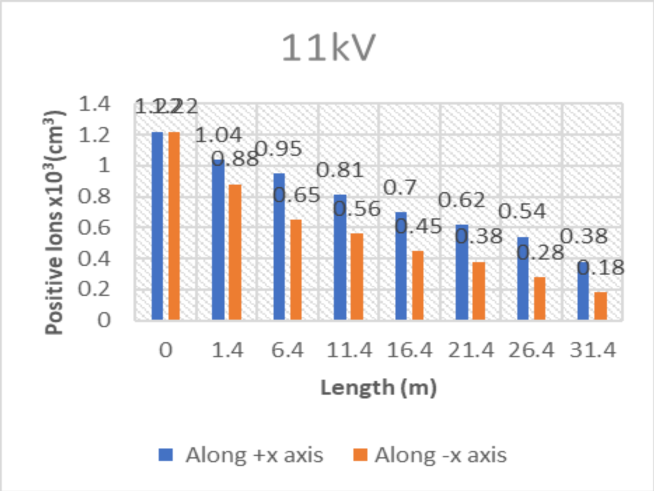

Figure 3. Measurement of Positive Ions along both +x and -x axes on 11kV at Supare-Akoko

This data suggests that the 11 kV power line at Supare-Akoko is a significant source of positive ions, with their concentration decreasing as the distance from the power line increases. The asymmetry in ion distribution might indicate the influence of environmental factors or the orientation of the power line relative to the measurement axes.

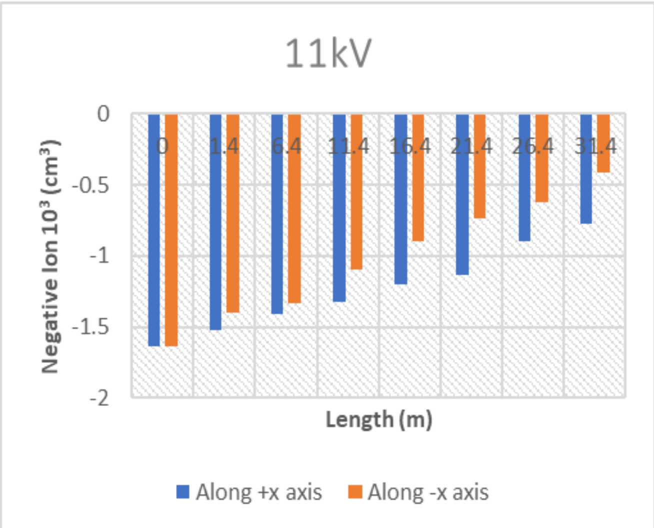

Figure 4. Measurement of Negative Ions along both +x and -x axes on 11kV at Supare-Akoko

The data indicates that the 11 kV power line at Supare-Akoko generates a significant number of negative ions, with their concentration reducing as one moves further away from the power line. The asymmetry in negative ion concentration between the +x and -x axes, similar to what was observed for positive ions, suggests that factors like wind direction, geographical features, or power line orientation may influence the distribution.

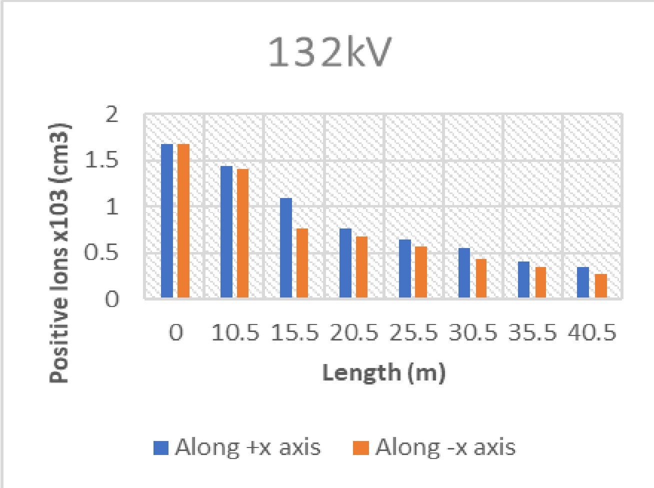

Figure 5. Measurement of Positive Ions along both +x and -x axes on 132kV at Akure

The data indicates that the 132 kV power line at Akure emits positive ions, decreasing their concentration as one moves further away from the line. The more symmetrical distribution of ions along both the +x and -x axes suggests that the factors influencing ion distribution, such as wind or terrain, may have less impact at this site compared to the 11 kV power line measurements. The results suggest that, at a higher voltage level, the power line's influence on ion distribution is more uniform, potentially affecting a broader area with a more consistent concentration gradient. This uniformity could have implications for environmental exposure to ionized air and understanding the broader effects of high-voltage power lines on the surrounding atmosphere.

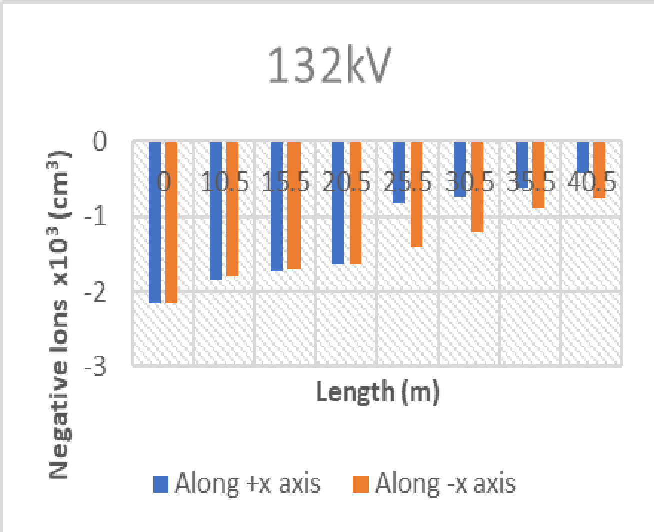

Figure 6. Measurement of Negative Ions along both +x and -x axes on 132kV at Akure

This data from Akure indicates that the 132 kV power line significantly influences the concentration of negative ions in its vicinity, with concentrations decreasing as one moves away from the line. The asymmetrical distribution, with a sharper decline along the +x axis, suggests that local environmental factors could affect these ions' spread.

Understanding the distribution of positive and negative ions is crucial for assessing the potential environmental and health impacts of exposure to ionized air near high-voltage power lines.

Corona discharges from an AC power line generate positive and negative ions, but the processes for each type are quite distinct. During the positive half-cycle, electrons near the line are stripped from atoms, creating positive ions. In contrast, electrons are primarily ejected through the photoelectric effect during the negative half-cycle. Negative ions typically have greater mobility than positive ions, allowing them to travel further from the line during their half-cycle and experience more ionizing inelastic collisions than the heavier positive ions [17].

It is generally observed that corona ion concentration reduces as we move further away from the centre of the High-voltage powerlines [18]. Unlike the positive corona ion concentration obtained during fieldwork, it was observed that the negative corona ion concentration is greater when compared to the value obtained when the Air Ion Counter (AIC) was placed on the positive polarity switch. The graph below (Figure 7 – Figure 10) analyses the corona ion concentration in ions/cm^3 with respect to the distance along the plain surface.

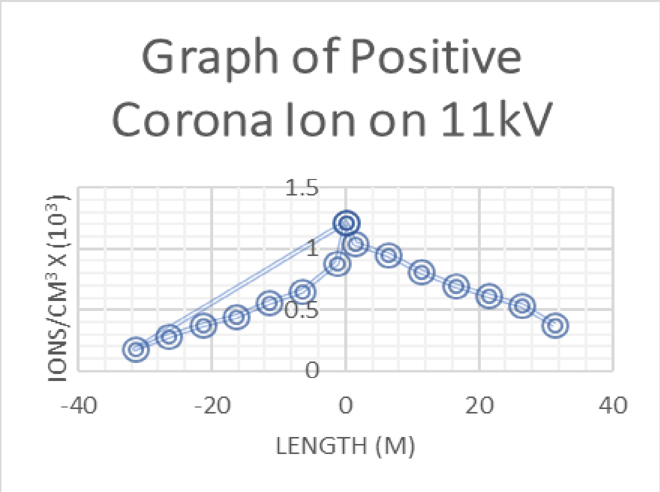

Figure 7. Graph of Positive Corona Ion Discharge from 11kV at Supare-Akoko

This graph from Supare-Akoko indicates that the 11 kV power line is a significant source of positive corona ions, with a concentration that decreases as the distance from the power line increases. The relatively symmetrical distribution along both axes suggests that local environmental factors might influence the ion spread, but not significantly. Understanding this distribution is important for assessing the environmental impact of corona ion discharge from power lines, particularly regarding how these ions interact with other airborne particles and the potential implications for air quality and health in the Supare-Akoko area.

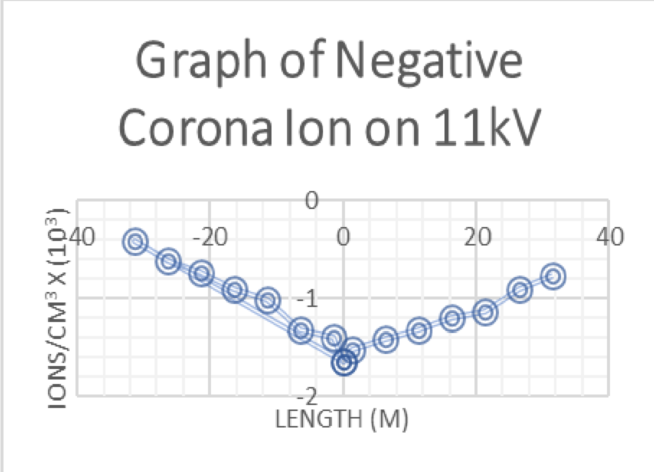

Figure 8. Graph of Negative Corona Ion Discharge from 11kV at Supare-Akoko

This graph from Supare-Akoko indicates that the 11 kV power line is a significant source of negative corona ions, with concentrations decreasing as the distance from the power line increases. The relatively symmetrical distribution along both axes suggests that local environmental factors might influence the ion spread, but not significantly. The slight differences between the +x and -x axes could be due to factors such as wind direction or the power line's orientation relative to the environment. Understanding the distribution of negative ions is important for assessing the environmental impact of corona ion discharge from power lines, particularly regarding how these ions interact with other airborne particles and the potential implications for air quality and health in the Supare-Akoko area.

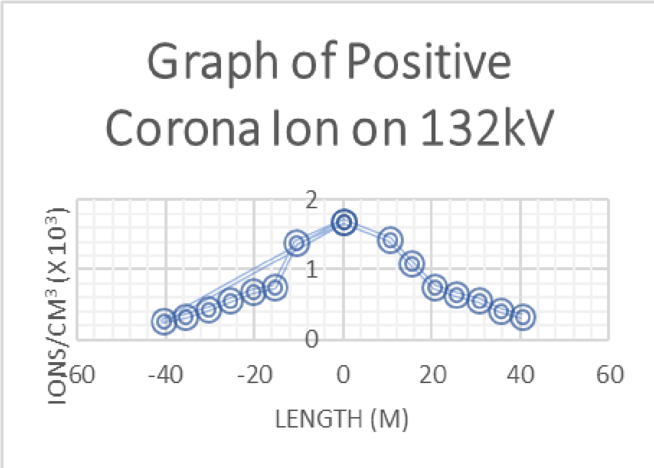

Figure 9. Graph of Positive Corona Ion Discharge from 132kV at Akure

This graph from Akure indicates that the 132 kV power line is a significant source of positive corona ions, with concentrations decreasing as the distance from the power line increases. The relatively symmetrical distribution along both axes, with slight differences, suggests that local environmental factors may influence the ion spread. Understanding this distribution is important for assessing the environmental impact of corona ion discharge from power lines, particularly regarding how these ions interact with other airborne particles and their potential implications for air quality and health in the Akure area.

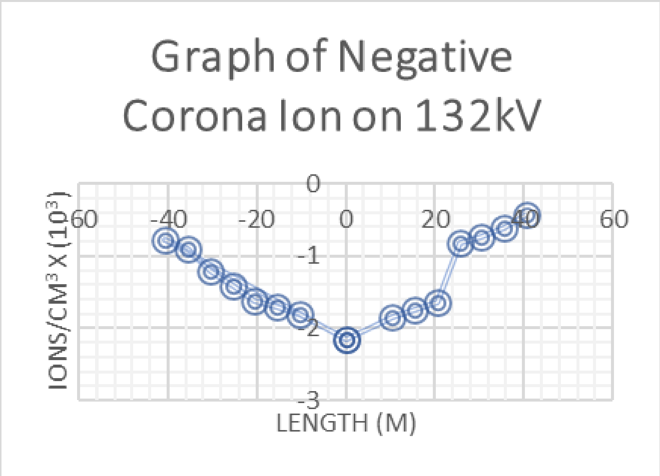

Figure 10. Graph of Negative Corona Ion Discharge from 132kV at Akure

This graph from Akure indicates that the 132 kV power line is a significant source of negative corona ions, with a noticeable decrease in concentration as one moves away from the line. The asymmetry in the distribution along the +x and -x axes suggests that local environmental factors could be affecting the spread of these ions, with a more rapid decrease along the +x axis. Understanding this distribution is important for assessing the environmental impact of corona ion discharge from high-voltage power lines, particularly regarding how these ions interact with other airborne particles and their potential effects on air quality and health in the Akure area.

The study's measurements of corona ion discharges from 11 kV and 132 kV power lines at Supare-Akoko and Akure reveal significant ion concentrations near the lines, with both positive and negative ions dispersing gradually as the distance increases. For instance, positive ion concentrations near the lines started at around 1.22 to 1.68 ions/cm³, while negative ions showed higher initial values of up to -2.16 ions/cm³. This consistent decrease in ion concentration with distance underscores a clear pattern of dispersion, indicating that the influence of these ions diminishes as they move further from the power lines.

While the ion distribution was generally symmetrical along the +x and -x axes for the 11 kV line at Supare-Akoko, some asymmetry was observed for the 132 kV line at Akure, particularly in the spread of negative ions. This asymmetry suggests that local environmental factors, such as wind direction or terrain, may affect how these ions disperse. The findings highlight the potential for localized environmental impacts due to high concentrations of ions near power lines, emphasizing the need to consider these factors when assessing the broader effects of corona ion discharges on air quality and public health.

5. Conclusion and Future Scope

Based on this study, it can be concluded that high-voltage power lines, particularly those operating at 11 kV and 132 kV, are significant sources of corona ion discharges, which lead to elevated concentrations of both positive and negative ions in their vicinity. These ions gradually disperse as they move away from the power lines, decreasing concentrations at greater distances. However, high initial concentrations near the power lines suggest potential localized impacts on air quality, which may be influenced by environmental factors such as wind and topography. The observed asymmetry in ion distribution at specific locations further underscores the importance of considering site-specific conditions when evaluating the environmental and health implications of corona ion discharges. Therefore, monitoring and assessing these effects, particularly in areas close to high-voltage power lines, is crucial to better understand their potential impacts on the environment and public health.

Corona effects result from the ionization of air caused by the strong electric fields present at the surface of sharp metallic points, thin wires, and similar structures on high-voltage power lines. Electrons entering the field are accelerated and gain sufficient energy to ionize air atoms upon collision. The resulting ion/electron pairs are also accelerated and collide, but only electron collisions lead to ionizing effects and initiate the avalanche breakdown process near the 'corona electrode.' This phenomenon is sometimes heard as a faint 'crackling' noise near power lines. Corona ions generated by the line are carried away by the wind and dissipate as the charged particles recombine or settle out.

Airborne pollutants inhaled into the respiratory system may deposit in various regions depending on their size, shape, density, and charge. The impact of corona ions on health depends on the level of pollutant exposure, the health effects of these pollutants, and the characteristics of the exposed individuals.

The production of corona ions is influenced by the strength of the electric field around the powerline fittings and conductors, known as the surface voltage gradient. To reduce the likelihood of corona, fittings with rounded corners and larger-diameter conductors are used. For very high-voltage lines (275 kV and above), using bundled conductors—several conductors per phase separated by spacers—or installing metallic corona rings around fittings can help spread the voltage gradient and reduce corona likelihood. Water droplets can increase the conductor surface voltage gradient, raising the chance of corona discharges during moist conditions like fog or rain, though this effect is temporary. Corona ion is densely concentrated at the centre of the powerline and is reduced as we move farther away from the centre of the powerline. Further investigations may include investigating the extent and patterns of pollutant deposition caused by corona ions in different environmental conditions and assessing the impact of corona ions on local flora and fauna, particularly focusing on species sensitive to changes in air quality. In addition, future research may involve designing and implementing real-time monitoring systems to detect and measure corona discharge and its effects on air quality and human health.

Data Availability

All data and materials used in this research can be obtained from the corresponding author upon a reasonable request.

Conflict of Interest

The authors have declared no conflict of interest in submitting and publishing this article.

Funding Source

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Authors' Contributions

P.A. Atepa researched literature, conceived the study, and was involved in protocol development and data collection. O.J. Ogunbiyi and O.O. Adekanye analyzed and interpreted the results. O.J. Ogunbiyi and P.A. Atepa wrote the first draft of the manuscript. All authors reviewed and edited the manuscript and approved the final version.

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